Tilled Fields Group Report for:

North **South**

Thank you for participating in the Citizen Science Soil Health Project. In 2019, 39 growers participated in the project. Together, we are figuring out the best ways to grow healthy soils in Colorado. This report is a summary of your farm's 2019 soil health outcomes. If you have questions about this report please contact:

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Participating growers - 2019

The Tilled-Fields Group

Keith Bateman - Bateman Farms
Ailsa Bier - Red Hen Farms
Elizabeth Black & Chris Brown - Christmas Tree Farm
JD Burch - Burch Farms
Bob Condon - Cottonwood Farm
Natalie & Jason Condon - Isabelle Farm
Anne Cure - Cure Organic Farm
Sarah Kell - Growing Gardens
Daphne Kingsley & Cameron Genter - Light Root Farm
Dan Lisco - Sombrero Farms
Catherine Long Gates - Long's Gardens Iris Farms
Marcus McCauley - McCauley Family Farms
Scott Miller - Rock Creek Farm
Michael Moss - Kilt Farm
Mike Munson - Munson Farms
Ben Pfeffer - Raisin Roots Farm
Sondra & Matthew Pierce - Matthew Pierce Farm
Susy Reuter & Jeff Russell - Flatiron Grass Fed Beef
Travis Rollins & Paul Hicks—Little Thompson Farm
Amanda & Brian Scott - 63rd St Farm LLC
John Schlagel—Niwot Farms
John Sekich - Sekich Land and Cattle Co
Kayann Short & John Martin - Stonebridge Farm
Eric & Jill Skokan - Black Cat Farm
Karel & Alice Starek - The Golden Hoof
Jules Van Thuyne - Van Thuyne Farms
Mimi Yanus - Mimi's Garden

The Zero-Tillage Group

Wyatt Barnes - Red Wagon Farms
Keith Bateman - Bateman Farms
Elizabeth Black & Chris Brown - Christmas Tree Farm
Dina Elder - Routt Gulch Tree Farm
John Ellis – Farmer John's
Rob Flemming - Saddleback Golf Course
Bill Howland - Nine Mile Ranch
Jake Jacobs - Flatirons Gold Course
Lauren Kolb – 4 OSMP ag sites
Kolb, Lezberg & Wanner – 15 OSMP wildland sites
Dan Lisco - Sombrero Farms
Catherine Long Gates - Long's Gardens Iris Farms
Hunter Lovins - Nighthawk Ranch
Gustavo Lozada – Nature First Farm
Marcus McCauley - McCauley Family Farms
Cody Oreck - Orchard House
Doug Parker & Ginny Jordan - Ginny's Farm
Susy Reuter & Jeff Russell - Flatiron Grass Fed Beef
Joe Schaap & Paula Shuler - Schaap-Shuler Farm
Karel & Alice Starek - The Golden Hoof
Dan Yechout - Bell Park Farm

HOW TO USE THIS REPORT

We have divided CSSHP growers into 2 peer groups based on tillage: the **Tilled Fields Group** and the **Zero Tillage Group**. One very clear trend in our data is that undisturbed grasslands, forests and perennial crops have higher soil health scores than row crops. Soil disturbance, that is tillage, has a large detrimental effect on soil microbial life and soil health scores. We realized that to be fair, we had to divide our growers into these two different peer groups. Most CSSHP growers are in just one peer group but 6 CSSHP growers tested several sites with different managements. These 6 growers are in both peer groups, and so they have received 2 reports, one for each group.

The table below shows how 12 important measurements of your soil compare to others in your peer group. Graphs on following pages show how you compare with peers on 3 management indicators of soil health: days of living cover, organic matter inputs and tillage intensity. Use these tests to identify strengths and constraints of your soil, and to figure out possible management changes.

	YOUR FIELDS		PEER FIELDS		
	North	South	Maximum	Median	Minimum
Soil Organic Matter	1.2	1	14.7	3.1	1
Soil Respiration	16.5	11.6	295	43.15	8.2
Water Extractable Organic Nitrogen (WEON) ppm N	20.7	22.7	50.7	18.25	8.1
Water Extractable 0rganic Carbon (WEOC) ppm C	203	213	644	213.5	82
Carbon Nitrogen Ratio	9.8	9.4	18.9	10.2	6.1
Soil Health Score	7.77	7.68	34.02	11.4	3.68
Soil pH	7.4	7.9	8.6	7.8	6.5
Available Nitrogen, lbs/acre	32.3	25.4	346.8	96.05	19.2
Available Phosphorus, lbs/acre	304.2	382.2	575.9	92.45	6.2
Available Potassium, lbs/acre	191.9	249.5	4308	200.4	56.6
Total Microbial Biomass	3208	3612	13309	3459	1041
Fungi:Bacteria ratio	0.289	0.246	0.435	0.216	0.054

DEFINITIONS:

Green = Good **Yellow = Average** **Red = Concerning**

Maximum: The highest score in your peer group

Median: Half your peers scored above this number and half scored below.

Minimum: The lowest score in your peer group

YOUR BIOLOGICAL SOIL HEALTH INDICATORS

	YOUR FIELDS		PEER FIELDS		
	North	South	Maximum	Median	Minimum
Soil Organic Matter	1.2	1	14.7	3.1	1
Soil Respiration	16.5	11.6	295	43.15	8.2
Water Extractable Organic Nitrogen (WEON) ppm N	20.7	22.7	50.7	18.25	8.1
Water Extractable 0rganic Carbon (WEOC) ppm C	203	213	644	213.5	82
Carbon Nitrogen Ratio	9.8	9.4	18.9	10.2	6.1
Soil Health Score	7.77	7.68	34.02	11.4	3.68

Soil Organic Matter (SOM) is the percent of your soil that contains large complex carbon-based organic molecules made from living things. SOM is the "house" that soil microbes live in. SOM helps form stable soil aggregates, improves the water-holding capacity of your soil, and provides a slow-release supply of nutrients.

Soil Respiration measures the CO_2 released in 24 hours by your soil microbes, and reflects the abundance and activity of your soil microbiome. Soil respiration is influenced by Soil Organic Matter (SOM), soil texture, overall fertility, soil type and climate. Sandier soils and dryer climates tend to score lower.

Water-Extractable-Organic Nitrogen (WEON) is the small water-soluble portion of the organic nitrogen in your soil organic matter (SOM). WEON is made up of large molecules like proteins, so it is not easily lost from your soil by leaching or volatizing. Soil microbes break WEON down into smaller nitrogen molecules and make them available to your plants.

Water Extractable Organic Carbon (WEOC) is the small water-soluble portion of your Soil Organic Matter (SOM) that your soil microbes can easily feed on. Soil Organic Matter (SOM) is the house that microbes live in, but WEOC is the food they eat. WEOC tends to respond to changes in management sooner than Soil Organic Matter (SOM).

WEOC:WEON Ratio is Haney's version of a Carbon: Nitrogen Ratio. It compares the water-soluble portions of carbon and nitrogen that are not yet tightly bound in Soil Organic Matter (SOM). Too little WEOC, and there is not enough for your soil microbes to eat. Too little WEON, and there is not enough extra nitrogen available for your plants. Scores of 8-15 are good and 10-12 are ideal.

Soil Health Score represents the overall health of your soil system. Tracking your Soil Health Score over time allows you to gauge the effects of your management. In Colorado, a score greater than 18 is hard to achieve. Colorado soils are limited by soil pH, soil texture, and annual precipitation. Front Range native soil types vary widely, so compare your soil health score to others nearby with similar native soil types to set realistic goals for what you can achieve.

YOUR CHEMICAL SOIL HEALTH INDICATORS:

	YOUR FIELDS		PEER FIELDS		
	North	South	Maximum	Median	Minimum
Soil pH	7.4	7.9	8.6	7.8	6.5
Available Nitrogen, lbs/acre	32.3	25.4	346.8	96.05	19.2
Available Phosphorus, lbs/acre	304.2	382.2	575.9	92.45	6.2
Available Potassium, lbs/acre	191.9	249.5	4308	200.4	56.6

Soil pH is a measure of how acidic or alkaline the soil is. pH controls how available nutrients are to crops. Most Colorado soils are alkaline, with a pH between 7.2 and 8.3. If pH is too high (alkaline), phosphorous, iron, manganese, copper and boron become unavailable to plants.

pH

pH<5.5 - Concerning | 6.2<pH >7.0 Good | pH>7.7 - Concerning

Nitrogen is an essential building block of all life and 78% of our atmosphere. It is a major component of chlorophyll, proteins and DNA. Plants cannot take nitrogen directly from the atmosphere but instead rely either on soil microbes to break down organic material into small nitrogen molecules which they can absorb, or on chemical fertilizers. Adequate nitrogen levels are different in different parts of the growing season, and for different crops.

ADEQUATE NITROGEN DURING THE FALLOW SEASON

N<20 – Concerning | N>50 - Concerning | N>100 - Excessive

ADEQUATE NITROGEN DURING THE GROWING SEASON

N<20 – Concerning (unless a legume) | 75< N >150 Adequate for most non-legume crops | N>300 - Concerning

Phosphorous is an essential plant nutrient, used by plant cells to build DNA and regulate metabolic reactions. At high levels, Phosphorous can pollute waterways and at very high levels it interferes with plant uptake of iron and zinc. A value of 50-100 is adequate for most crops.

ADEQUATE PHOSPHORUS

P<20 - Concerning | 50< P >100 Good | P>300 - Concerning

Potassium is an essential plant nutrient that helps with heat and cold tolerance and promotes fruit development. Potassium levels are adequate to high in most Colorado soils, especially with annual applications of compost or manure. Deficiencies occasionally occur in soil with low SOM and in sandy soils. A value of 100-500 is adequate for most crops.

ADEQUATE POTASSIUM

K<50 - Concerning | 100< K >500 Good | K>2000 - Excessive

YOUR SOIL'S MICROBIAL LIFE

	YOUR FIELDS		PEER FIELDS		
	North	South	Maximum	Median	Minimum
Total Microbial Biomass	3208	3612	13309	3459	1041
Fungi:Bacteria ratio	0.289	0.246	0.435	0.216	0.054

Total Microbial Biomass represents the total microbial life in your soil. pH, temperature, moisture, soil type, Soil Organic Matter, intensity/type of tillage, crop rotations, cover crops, and herbicide or pesticide applications will all change this number. The higher the number, the more varied your microbial community is, and the better your soil health is. There is no baseline "normal range" for biological testing like there is for chemical analysis. These numbers are most useful for comparing different management over time.

Fungi: Bacteria Ratio

Bacteria are the smallest, most plentiful and hardiest microbes in your soil. They can survive under harsh conditions like tillage. However, as single-celled organisms, they need a film of water to survive. When conditions are ideal, bacteria reproduce in 30 minutes, and have a short life span. Bacteria contain a lot of Nitrogen because they are the first microbes to digest new organic residues in the soil. When bacteria die, the Nitrogen in their cells is released to the soil in plant-available forms. Bacteria are like little bags of fertilizer that power your soil nutrient cycle.

Fungi are rapid-growing multi-celled organisms that need a constant food source. They form symbiotic relationships with plants, by tapping directly into a plant's roots for food. In exchange, Fungi send hyphae, or threads, many feet out into the soil to gather and transport water and nutrients back to the plant. They prefer slightly acidic, low disturbance soils, and high carbon residues. They are not as hardy as bacteria, and decline with conventional tillage. Fungi are good at storing Carbon in the soil.

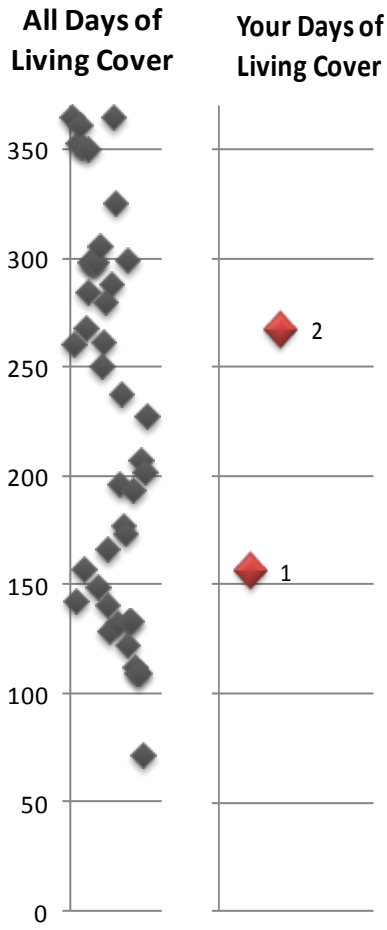
Your **Fungi : Bacteria Ratio** will always be less than 1 because bacteria are much more plentiful than fungi. Bacteria are important and needed, but Fungi are desired and usually indicate good soil health. Cover crops, organic inputs and less tilling will help your soil support more Fungi. Forests tend to have fungal-dominated soils. Highly productive agricultural soils tend to have higher ratios of Fungi to Bacteria. Grasslands and agricultural soils usually have bacterial-dominated soils. Bacteria dominate in early spring or late fall, in systems with fewer organic inputs, under dry conditions, in alkaline soils, and after tillage, grazing or compaction of soil.

HOW TO READ THESE GRAPHS: We used the data from your farm management sheets to calculate 3 key indicators of soil health management: days of living cover, tillage intensity, and off-field organic matter inputs. For each indicator, we've plotted results from your farm relative to results from peer farms. In each graph, the gray dots show peer fields, and the red dots show your fields.

YOUR DAYS OF LIVING COVER

Living vegetation protects soil from wind and water erosion while also supplying the soil with fresh organic matter and feeding the soil microbiome. Linking together crops and cover crops to maximize days of living cover is a fundamental soil building practice. The "Days of Living Cover" score is the days between crop or cover crop seeding (or transplant) and termination (or winter kill).

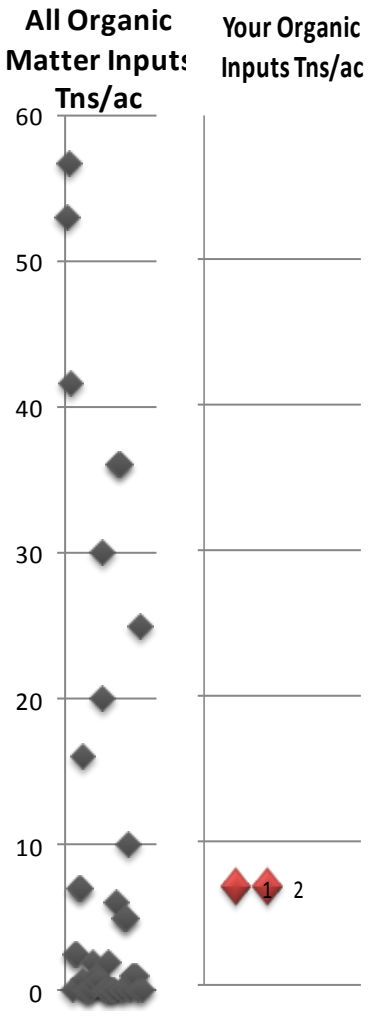
	YOUR FIELDS		PEER FIELDS		
	Name	Days	Maximum	Median	Minimum
1	North	157	365	232	72
2	South	268			
3					
4					



YOUR ORGANIC MATTER INPUTS

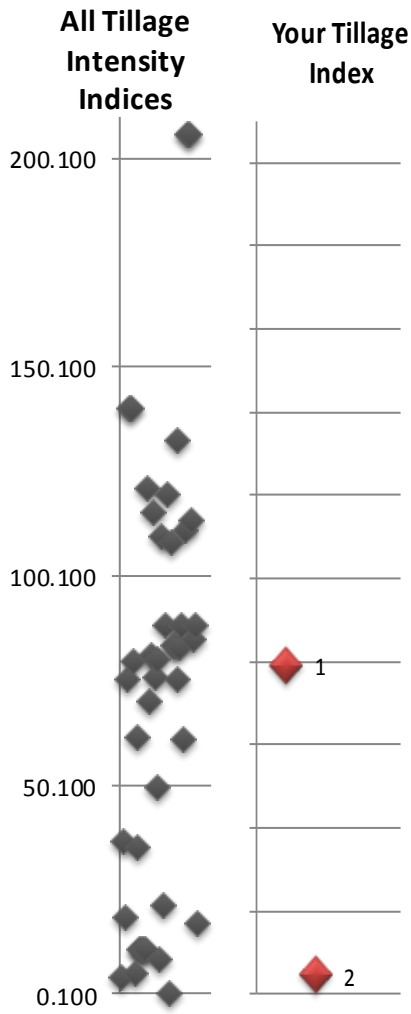
Organic matter inputs including composts, manures, and straw mulches can jump-start the formation of soil organic matter, add microbiology to the soil, and supply macro and micro nutrients. However, continuous inputs can also contribute to soil health challenges, such as excessive phosphorus levels. This organic input score shows the total organic inputs (composts, manures, and mulches) into each field, in units of tons per acre. This indicator only looks at inputs from "outside" the study field, and doesn't include manure deposited by animals grazing in that field or biomass generated by crops and cover crops.

	YOUR FIELDS		PEER FIELDS		
	Name	Tons/Ac	Maximum	Median	Minimum
1	North	7	56.7	1	None
2	South	7			
3					
4					



YOUR TILLAGE INTENSITY INDEX

Tillage can degrade soil structure and organic matter, but it can also be a valuable tool for weed management and incorporating cover crops and other organic material. The tillage intensity index uses data from a Natural Resources Conservation Service soil erosion model to assign a soil disturbance score to all farm operations that can compact or disturb soil. For context, NRCS assigns a single pass with a chisel plow a score of 62.4, a disc harrow gets a score of 19.5, and a seeder gets a score of 0.585. At the bottom of the page is a table of your implements and the tillage scores we assigned for your fields.



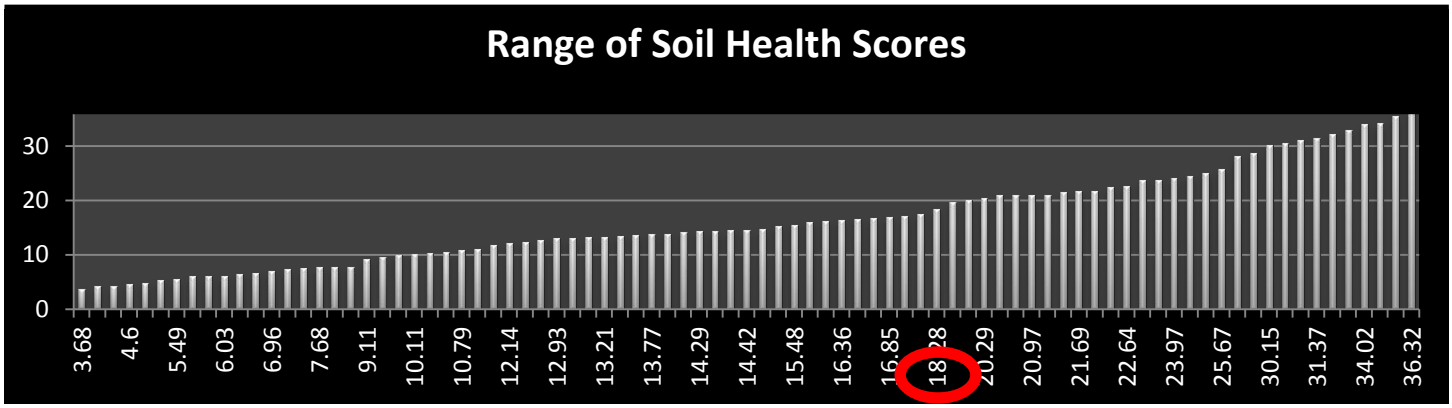
	YOUR FIELDS		PEER FIELDS		
	Name	Score	Maximum	Median	Minimum
1	North	79.6531	205.72	79.77405	0.15
2	South	5.03			
3					
4					

Field	Operation	# Passes	Depth	% Disturbed	Tillage Intensity Index	Total Tillage Index
North	strip till	1	15	20	17.1031	
	Field cultivator	2	3	100	62.4	
	Mowed corn and cover to terminate	1			0.15	
						79.6531
South	No-till drill for oats	1	0	0	4.88	
	Mowed oats to terminate	1	0	0	0.15	
		0	0	0	0	0
		0	0	0	0	0
		0	0	0	0	5.03
0		0	0	0	0	0
		0	0	0	0	0
		0	0	0	0	0
		0	0	0	0	0
		0	0	0		0

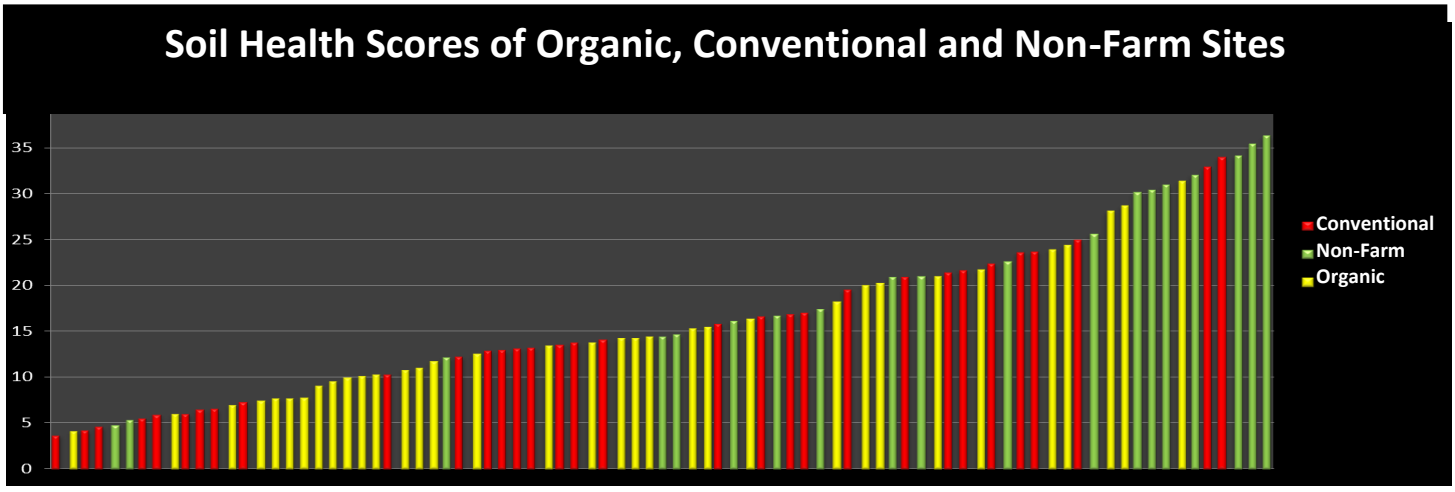
INSIGHTS FROM OUR BASELINE DATA

There is a great deal of variability in a citizen science project such as ours. Native soil types vary widely across the Front Range, and our growers use widely varying management systems Half our growers are sampling soils in the spring, when plant roots are small, supplying minimal carbon sugars to a growing soil microbiome. The other half of our growers are sampling in the fall, when a large influx of root exudates feed plentiful soil microbes. This last spring was exceptionally wet. Our data will be much different when we encounter our next drought. The inherent variability in a citizen science project is why we are comparing each grower ONLY with themselves over a 10 year-long project.

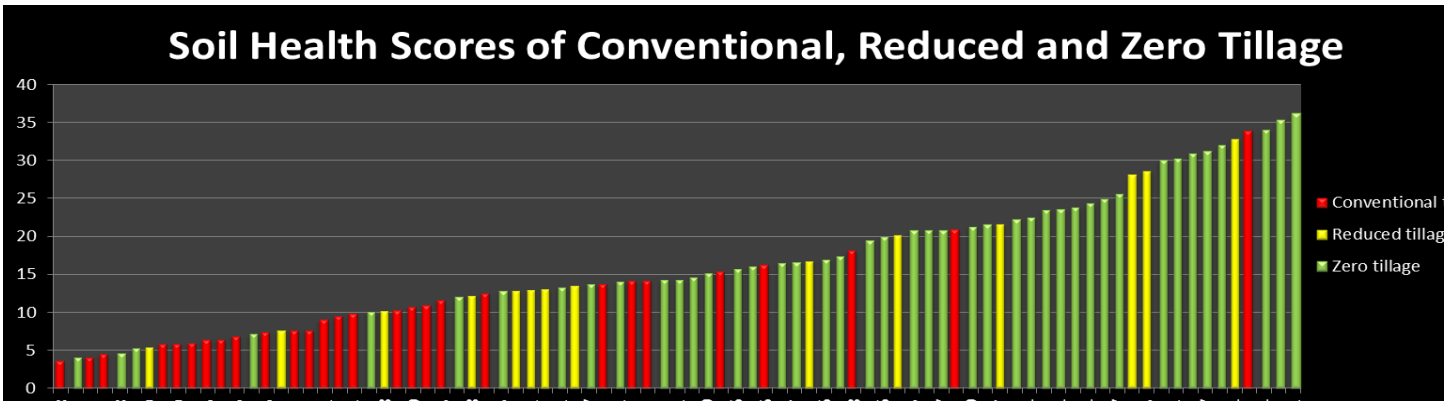
Our preliminary findings are only a snapshot of current conditions on Boulder, Weld and Larimer County lands. They do NOT tell us whether our overall soil health is improving or degrading. That is why our growers will continue to test their soil over the next 10 years, so they can find out which direction their soil health is headed, and which practices improve their soil health the fastest and the most.



There's a huge range of soil health scores across our area, from a low of 3 to a high of 36. Scores over 18 are rare in Colorado, so we should be quite proud of our high scorers. This hopeful graph shows what's possible in our area. We CAN get good soil health scores and sequester more carbon here. There's lots of up-side potential for some of our lower scoring fields.



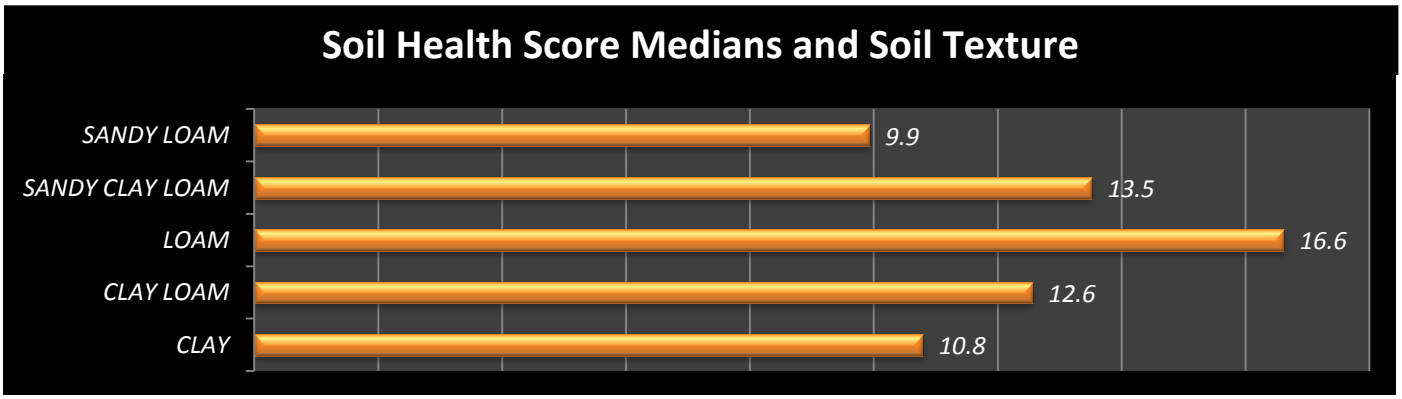
Organic sites (median Soil Health Score 13.62), the yellow bars on the graph, use only organically certified compost, manure, fertilizers and pesticides. **Conventional sites** (median Soil Health Score 13.67), the red bars, use all kinds of compost, manure, fertilizers and pesticides. **Non-Farm sites** (median Soil Health Score 20.97), the green bars, are where no crop is grown, like uncultivated abandoned farm fields, forests, or grasslands. Our Organic and Conventional growers have the same median soil health score of 13.6. So based on our current snapshot, organic growing methods are NOT better than conventional growing methods in terms of soil health. However the Non-Farm group beat them both.



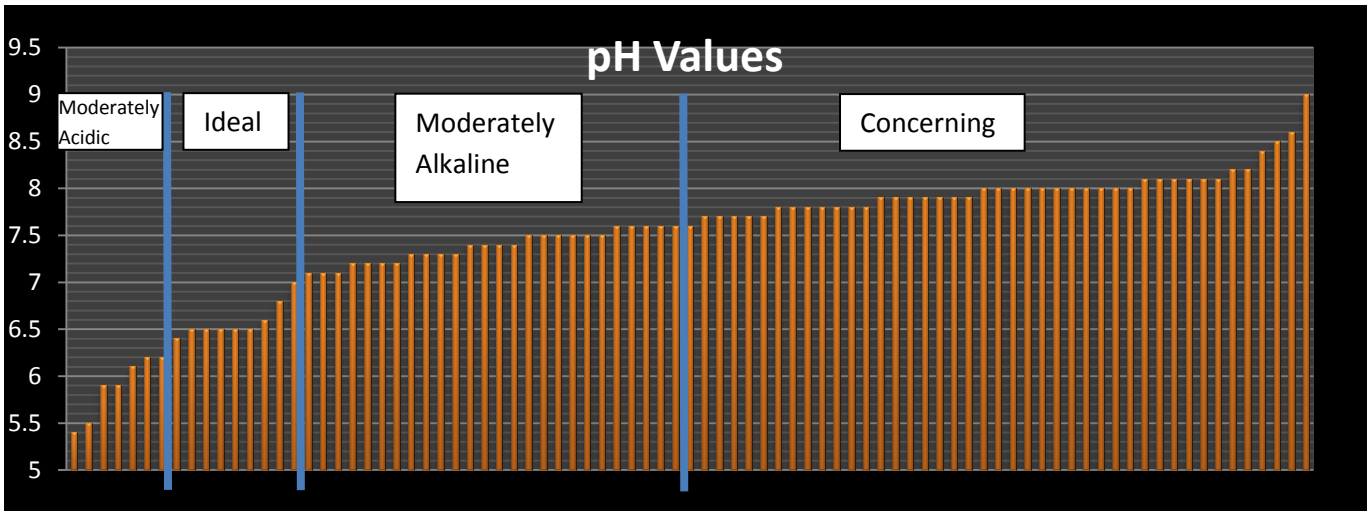
When our 96 sites are analyzed according to tillage intensity, a clear pattern emerges. Our **Zero Tillage** sites, (median Soil Health Score 20.05), the green bars on the graph, include irrigated pastures and hayfields, as well as dryland Open space grasslands and forests. Our "Non-Farm" sites in the previous graph all are included in this zero tillage category. **Reduced Tillage** sites (median Soil Health Score 13.39), the yellow bars on the graph, included growers using strip-till with herbicides and GMO's, small garden plots with only hand-tool-tillage, and chisel and key-line plowing, which disturbs the soil less. **Conventionally Tilled** sites (median Soil Health Score 9.76), the red bars on the graph, include growers who use moldboard plows and lots of mechanical cultivation. Median Soil Health Scores fall as tillage intensity increases between our 3 tillage categories, so we can conclude that more intense tillage has a detrimental effect on soil health.

Irrigated and Dryland Median Soil Health Scores		
Tillage	**Irrigated**	**Dryland**
Zero Tillage	**20.94**	17.26
Reduced Tillage	**15.21**	7.88
Conventional Tillage	**9.94**	6.53

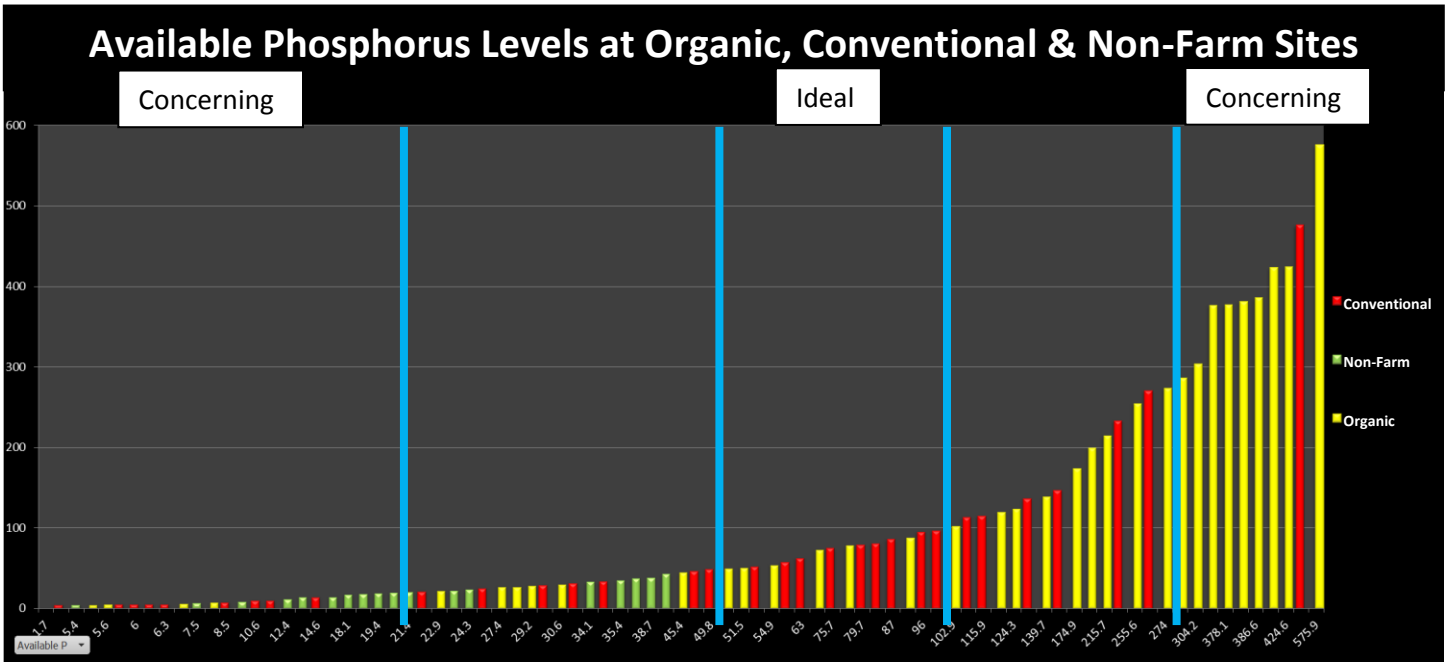
When our 96 samples are grouped according to tillage intensity, and then examined for the effects of supplemental irrigation, another pattern emerges. Sites receiving supplemental irrigation water all had higher medians than comparable dryland sites in their same tillage category. Supplemental irrigation water improves soil health scores and soil carbon sequestration. Water is LIFE! Based on these two previous graphs, our two big takeaways from the CSSHP so far are: 1) If you have supplemental life-giving irrigation water, you can expect a better Soil Health Score, and 2) If you disturb your soil less and till less intensively, you can expect a better Soil Health Score.



We also examined the effects of soil texture on Soil Health Scores, and no surprise, our loamiest soils have the better Soil Health Scores. This graph shows the medians of the Soil Health Scores of all the different soil types. The loamy median has the longest bar and highest median, and scores fall off above and below loam, to clay and sand which have the lowest Soil Health Scores. Loam soils are made up of sand, silt and clay particles. Because of this mix of different sized soil particles, loams allow water, air and roots to penetrate easily. Loams also retain moisture, nutrients and organic matter better than other soil types.



The Front Range is known for its alkaline soils and we are certainly seeing that. Less than 20% of our sites have pH values in the “Ideal” or “Moderately Acidic” Range, and many of them are forested sites in the mountains. The vast majority of our sites have alkaline soils, and about half of all our sites are in the “Concerning” range, with a pH above 7.7.



The final trend in our preliminary findings pertains to Phosphorus. At high levels, Phosphorous can pollute waterways and at very high levels it interferes with plant uptake of Iron and Zinc. Optimal values for Available Phosphorous are generally between 50 and 100. Values above 300 are concerning and warrant attention. Excessive soil Phosphorus is a common problem in organic production because of the relatively high concentration of Phosphorus in manure and some compost. All our Non-Farm sites had quite low Phosphorous levels (<50). However, 10 sites (9 organic and 1 conventional) had Phosphorus levels above 300. These growers are advised to

- Switch to low-Phosphorus amendments
- Incorporate legume cover crops to boost nitrogen but not Phosphorus
- Ensure adequate buffer strips along fields to slow and absorb nutrient run-off and protect waterways
- Run plant tissue analyses for Iron and Zinc if deficiencies are suspected